

# Quality Metal Finishing Guide

## Zinc and Cadmium Coatings



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## DESIGN FOR PLATING

The program to improve and control the quality of a metal product should start at the desk of the designer. Basic principles of mechanical finishing and electroplating impose important restrictions on the size and shape of components. The designer should know enough about these principles so that he can design to minimize costs of quality finishing while planning products which will have a long service life. Metal finishing processes are at least as complicated as metal stamping, casting or forging with which the designer is usually more familiar. Proper selection of finishes and processes offers many opportunities to improve quality, reduce costs, and increase production. ASTM Designation B-507 can provide the designer with helpful information.

### **Significant Surfaces**

A most important term used when specifying metal finishes is "significant surface" because on many products the same standard of quality is not required at all points on the surface. The significant surfaces can be defined as those normally visible directly or by reflection which are essential to the appearance or serviceability of the article or which, if they are a source of corrosion products, can alter the appearance or performance of visible surfaces. Significant surfaces preferably should be agreed upon between purchaser and manufacturer and should be indicated on drawings. Furthermore points at which thickness measurements are to be made should be identified.

### Design for Barrel Processing (Electroplate or Mechanical Plate)

Metal parts which are to be zinc or cadmium plated do not ordinarily require polishing with belts or wheels before plating. Those to be cleaned or smoothed are often treated by barrel finishing or tumbling or other vibrating processes. In designing to improve quality, consideration should be given to certain rules applicable to such processing, whether this be surface preparation or barrel plating:

- Avoid blind holes, recesses and joint crevices which can retain tumbling compounds and metal debris.
- Avoid intricate surface patterns which will be blurred by barrel finishing.
- Parts must be sturdy enough to withstand the multiple impacts of barrel rotation.
- Small flat parts which tend to nest together should be provided with ridges or dimples to prevent this.
- Design for good entry and drainage of solutions during rotation by using simple shapes.
- Significant surfaces must be exterior for barrel work in order to undergo proper mechanical preparation and cleaning or to receive their share of metal deposit. They should be convex, if possible, rather than recessed.

### Design for Racking, Draining and Air Entrapment

There are design considerations other than the above for parts which are to be mounted on racks for processing in cleaning and electroplating tanks. Among them are the following:

- Products which would occupy a volume in processing tanks large in proportion to surface area should be designed to be plated in sections for assembly after coating.
- Consult the plating department to make certain that parts can be held securely on a plating rack with good electrical contact without masking any significant surface. Many difficult racking problems can be solved by design modification.
- Provide for good drainage of cleaning and other processing solutions from racked parts. Certain shapes tend to trap solution which then cause contamination by carryover, possible corrosion of the part and wastage of materials. Carryover also aggravates the problem of waste disposal. In design avoid rolled edges, blind holes and spot-welded joints. Provide drain holes in recessed areas.

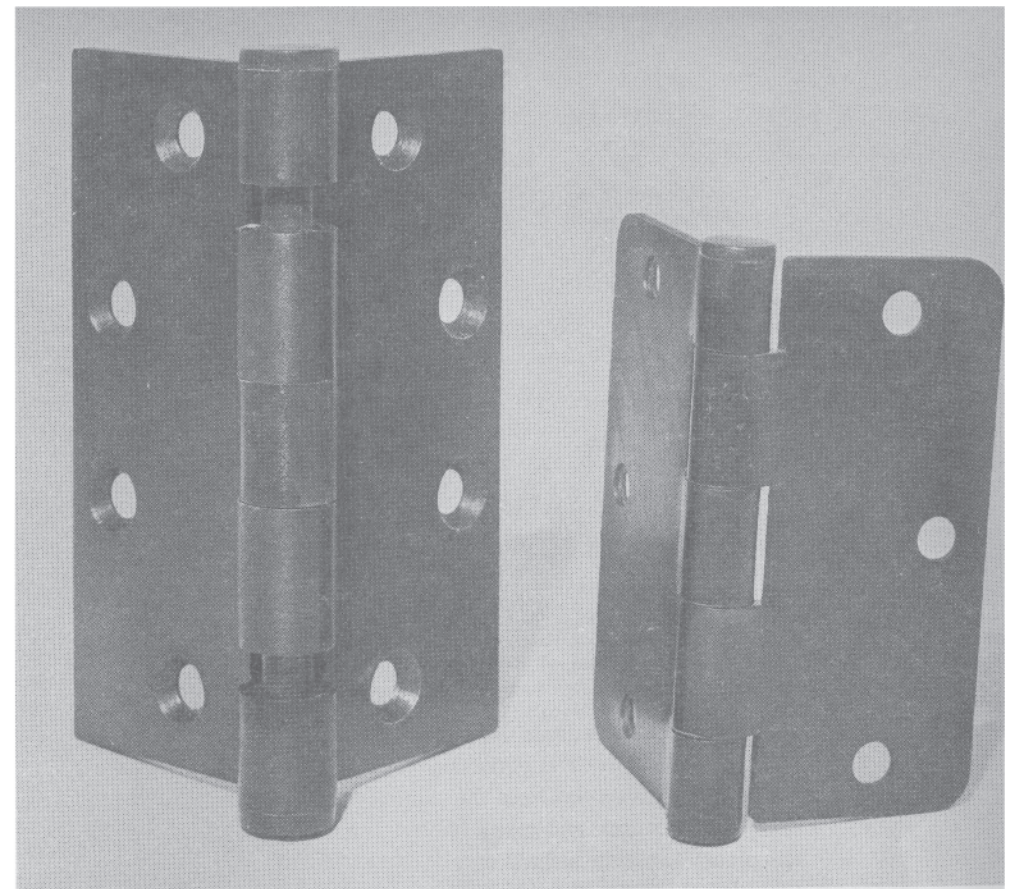


Illustration B — Zinc plated steel hinges, chromate treated and dyed black.

- Avoid shapes which can trap air on entry into a processing tank if this air can prevent access of solutions to areas requiring treatment. Wherever air can be trapped, hydrogen or oxygen may also accumulate during cleaning and plating.

### Design for Good Distribution of Electrodeposits

The most important factor determining the quality of a coating on metal parts is its thickness on significant surfaces. Fundamental laws of electrochemistry operate to prevent perfectly uniform deposition of an electrodeposit on a cathode of any useful shape and size. Portions of the work which are nearer to the anodes tend to receive a heavier deposit. Sharp edges or protrusions tend to steal a larger share of the current and receive a heavier deposit. The goal of the designer and the plater is to minimize thickness variations over significant surfaces. At the same time uneconomical wastage of metal by excessive build-up on non-significant areas must be avoided. Variations in plate distribution may not allow parts to be assembled properly due to heavy buildup in high current density areas.







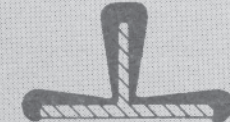
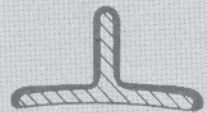





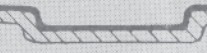
## DESIGN FEATURES THAT INFLUENCE ELECTROPLATABILITY

The effect of the basic design of a product or component upon the effectiveness or durability of the plating used has been the subject of much study and research and many failures for which the plater has been blamed can be attributed to the original design.

A major contribution to the plating industry was made by the Zinc Institute, Inc. when it sponsored a design study by Battelle Memorial Institute which has resulted in the establishment of basic design principles to be applied to zinc die castings.

The various shapes shown here provide the "do & don'ts" of design configurations and their relationship to electroplating quality.

Courtesy Zinc Institute, Inc.

		INFLUENCE ON ELECTROPLATABILITY	
		Feature	Better Design
Convex surfaces		Ideal shape. Easy to plate uniformly, especially where edges are rounded.	
Flat surfaces		Not as desirable as crowned surfaces. Use a .4mm/25.4mm (1/64 inch/inch) crown to hide undulations caused by uneven buffing.	
Sharply angled edges		Undesirable. Reduced thickness at center areas and requires increased plating time for depositing a minimum thickness of durable electroplate. All edges should be rounded. (Edges that will contact painted surfaces should have a minimum radius of .8mm [1/32 inch]).	
Flanges		Large flanges with sharp inside angles should be avoided to minimize plating costs. Use a generous radius on inside angles and taper the abutment.	
Slots		Narrow, closely spaced slots and holes reduce electroplatability and cannot be properly plated with corrosion-protective nickel and chromium unless corners are rounded.	
Blind holes		Must usually be exempted from minimum-thickness requirements. Where necessary limit depth to 50% of width. Avoid diameters less than 6mm (7/32 inch).	
Sharply angled indentations		Increase plating time and costs for a specified minimum thickness and reduce the durability of the plated part.	

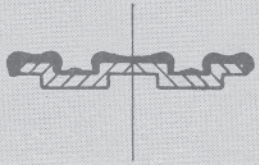
**INFLUENCE ON  
ELECTROPLATABILITY**

Feature

The distribution of electroplate is indicated in an exaggerated fashion

Better Design

Flat-bottom grooves



Inside and outside angles should be rounded generously to minimize costs.



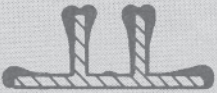
V-shaped grooves



Deep, V-shaped grooves cannot be satisfactorily plated with corrosion-protective nickel and chromium and should be avoided. Shallow, rounded grooves are better.



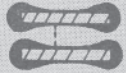
Fins



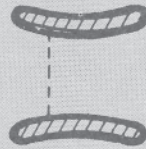
Increase plating time and costs for a specified minimum thickness and reduce the durability of the plated part.



Ribs



Narrow ribs with sharp angles usually reduce electroplatability; wide ribs with rounded edges impose no problem. Taper each rib from its center to both sides and round off edges. Increase spacing if possible.



Concave recesses



Electroplatability is dependent upon dimensions.



Deep scoops



Increase plating time and costs for a specified minimum thickness.



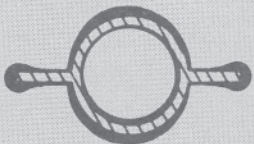
Spearlike juts



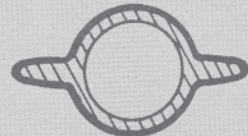
Buildup on jut will rob corners from their share of electroplate. Crown the base and round off all corners.



Rings



Electroplatability is dependent upon dimensions. Round off corners and crown from center line, sloping towards both sides.



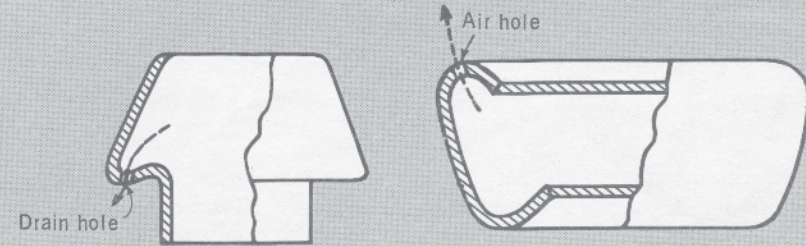
**DESIGN  
FOR  
PLATING**



Uniform plating

Plating missed

**AVOID SHARP  
INTERIOR ANGLES**



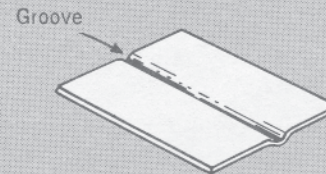
Drain hole

Air hole

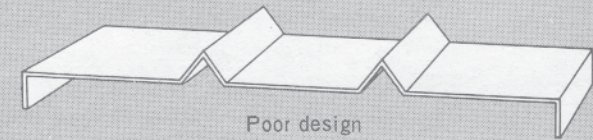
**PLACE HOLES FOR  
DRAINING AND AIR ESCAPE**



Good design

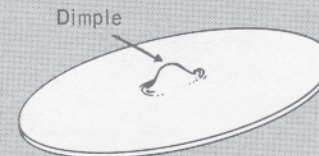


Groove



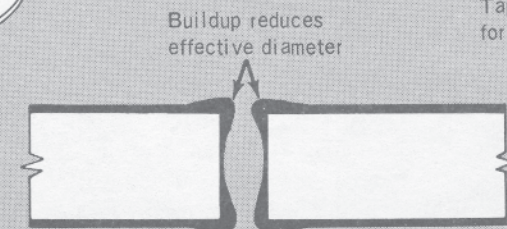
Poor design

**ROUND OFF HIGH SPOTS**



Dimple

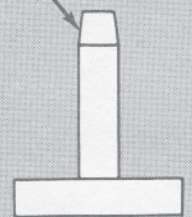
**AVOID STICKING  
WHEN BARREL PLATING**



Buildup reduces effective diameter

Hole

Tapered end to allow for buildup



Plug

**ALLOW FOR BUILD UP**

It is possible to estimate metal distribution ratios from models or mock-ups, but there are also empirical rules which can guide the designer to improved uniformity of thickness, hence to improved quality with greater economy. The sketches illustrate the influence of design as it has been developed from practical experiences:

- Avoid concave or perfectly flat significant surfaces. Convex or crowned areas receive more uniform coating.
- Edges should be rounded.
- Reentrant angles or corners should be filleted with a generous radius. Make such radii as large as possible.
- Blind holes must usually be exempted from minimum thickness requirements.
- Protruding fins, knobs and ridges tend to rob current from surrounding areas, hence should be avoided or reduced in height.
- Assist the plater by clearly marking significant surfaces in part drawings.
- Avoid use of a variety of basis metals in any one part to be plated. The contact of dissimilar metals may interfere by galvanic action with covering power or with adhesion of the deposit. In addition, the cleaning of dissimilar metals is quite difficult, if not impossible.

#### Design for Good Distribution of Mechanical Plating

There is available a non-electrolytic, mechanical plating process which utilizes mechanical energy to deposit metal coatings in a tumbling barrel. The designer should be aware that the distribution of thickness follows different rules than in electroplating. Mechanical plating tends to form thinner coatings at edges and corners than on adjacent surfaces. Flat surfaces are well covered but blind holes and reentrant angles are not. Some recessed areas such as the root diameter of threads have a tendency to build-up. It is evident that, in spite of these differences from electroplating, the designer should still avoid sharp edges and corners, as well as blind holes, to aid in improving quality.

#### SELECTING THE FINISH

The designer should approach the problem of selecting a zinc or cadmium finish with a clear understanding of the requirements expected of the coating, the properties of the metal deposit, the properties of any coating on the deposit and the service conditions the article will be expected to withstand. Another factor to consider when choosing zinc or cadmium is that some countries will not allow parts or assemblies to be imported if they contain cadmium.

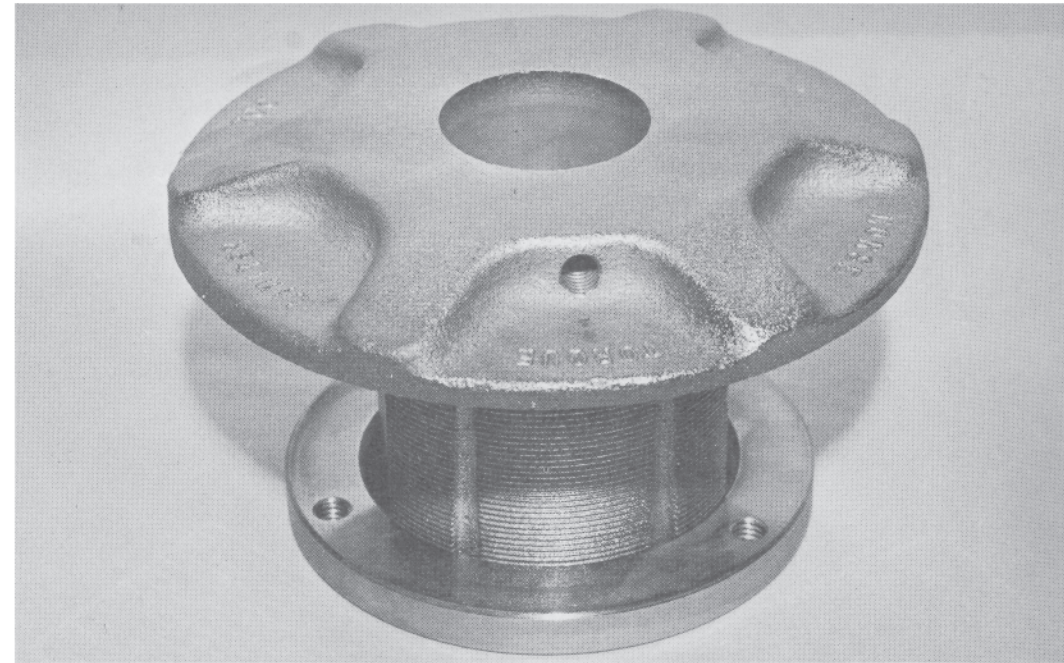


Illustration C — Zinc plated cast iron torque limiter assembly with iridescent chromate coating for indoor service on electric motor.

In most cases pleasing appearance is an important factor regardless of function. A properly selected finish of high quality will have an acceptable appearance not only on the shelf but also throughout the service life of the part.

#### Requirements of Finish

Iron and steel surfaces rust readily even in mildly corrosive surroundings. The rust not only is unattractive but may interfere with mechanical functioning of a component or discolor materials in contact with it. Nearly all iron and steel structures or parts are therefore treated for rust prevention. Zinc and cadmium deposits afford excellent protection against rusting under most circumstances. The reason for applying zinc or cadmium may be classified as: (a) to retard rusting, (b) to provide a pleasing appearance and (c) to serve in some functional capacity.

- (a) Rust Prevention** — The corrosion rates of zinc and cadmium deposits are much lower than those of steel in most atmospheres as well as in contact with water. In addition, the electrochemical relationships between each of these two metals and steel are such that rusting of the latter is suppressed by galvanic action even where the coating is damaged or worn through.

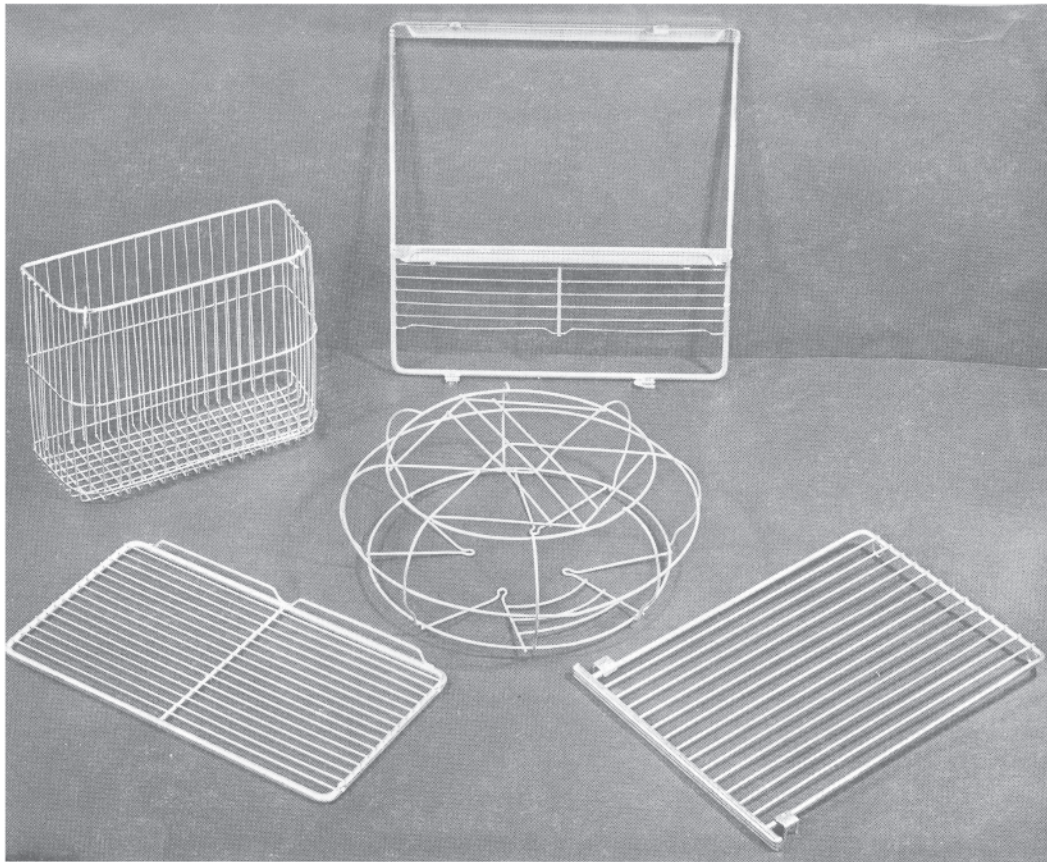


Illustration D — Zinc plated steel wire goods with anodic clear chromate coating plus baked clear enamel.

- (b) **Appearance** — In some applications zinc or cadmium is used with the sole objective of providing a durable, pleasing appearance for the period of useful life of a steel part. Applications of this class have been greatly increased by the availability of bright zinc and cadmium deposits and the development of chromate conversion coatings and colored finishes.
- (c) **Functional Service** — Zinc or cadmium may be deposited on steel components to serve functional purposes while retarding rusting. Examples of such uses are: (1) to improve solderability, to lower electrical contact resistance and to provide surface conductivity on electronic equipment, radio and television chassis, (2) to prevent discoloration of fabrics or other materials with

which the plated coating may be in contact, (3) to prevent seizing of moving parts, bolts, nuts and latches, (4) to reduce or eliminate bi-metallic corrosion through the use of mixed metal mechanically deposited coatings.

#### Properties of the Deposited Metal Coatings

Cadmium and zinc, considered similar in their galvanic behavior to iron in most environments, do differ in many of their properties. These differences should be considered in selecting one for a given application.

- (a) **Rust Retardation** — The potential difference between cadmium and iron is usually less than that between zinc and iron. For this reason cadmium does not retard rusting over as large an area of exposed iron as does zinc. “Pinhole” corrosion of steel is occasionally observed to occur through pores in a cadmium coating. This suggests that the potentials of cadmium and iron may even be reversed in some environments.

Exposure tests have shown conclusively that in industrial locations cadmium coatings fail more rapidly than do zinc coatings of equal thickness. In severe marine atmospheres, however, cadmium is more effective than zinc in retarding rusting. These results have also been shown to be independent of the application method. Mechanically deposited coatings have demonstrated equivalence to electro deposited coatings of these metals when equal thicknesses have been compared.

The slower rate of corrosion of zinc deposits in industrial atmospheres has been attributed to the fact that zinc corrosion products formed in such atmospheres are alkaline in character and of low solubility. Cadmium corrosion products in industrial atmospheres are more soluble and tend to wash away. It is not clear why cadmium outperforms zinc in the salt spray and in pure marine atmospheres. The zinc corrosion products formed under these conditions are visible enough but do not seem to be as protective.

When rust retardation is the prime requirement zinc coatings are commonly used. The zinc coating may be untreated or receive an inexpensive clear chromate finish in such applications, as for example, conduit, strip, wire and fence hardware.

- (b) **Corrosion Behavior** — When zinc is stored in a humid, stagnant atmosphere quantities of white, bulky corrosion products develop which are usually objectionable and may interfere with proper functioning of moving parts or cause seizure of threaded components. Cadmium weathers differently and does not generate voluminous adherent corrosion products. Corrosion of this sort usually can be prevented by application of chromate conversion finishes.



manufactured today is given a thin (20 micrometres maximum) protective film using one of the available chromate conversion finishing processes. There are three classes of chromate finishes in general use on cadmium and zinc coatings blue brite, clear (single dip or leached) iridescent yellow, black and olive drab. The thickness of the finish increases in the same order, the olive drab being relatively much thicker than the others. Which class of finish is selected depends upon the kind of service to be met and the properties desired in the finish.

- (a) **Corrosion Protection** – The protective value of a chromate finish increases with increasing thickness. In a salt spray test bare zinc-coated steel may show white corrosion products in an hour or two. The same parts, given an olive drab chromate finish can withstand more than 100 hours exposure before showing white products. The protection afforded is particularly valuable in retarding white corrosion under highly humid storage conditions in stagnant air. When used as a base for paint or other organic coating, the chromate coating is extremely beneficial in that it forms a barrier to lateral erosion and undercutting of the top coat. Applications benefiting by this protection include auto parts, washing machines, refrigerator parts and military hardware and equipment intended for tropical service.

Trivalent chromium processes for developing Chromium – containing film on zinc and cadmium are available. The film produced is used similarly as a base for organic finishes and gives improved corrosion resistance to the final product when used in this fashion. The corrosion protection afforded by the film alone is generally equal to a single-dip blue-bright hexavalent chromate process.

- (b) **Decorative Value** – The use of chromate finishes permits wide choice in surface appearance. The chrome-like brilliance of bright zinc or cadmium can be preserved for extended periods of time indoors by application of a blue brite, clear or leached chromate finish. Further protection can be provided by a clear lacquer coating. Tubular furniture and business machine parts are typical examples.

The thicker finishes offer variety in color ranging from yellow through iridescent yellow to bronze, black, and olive drab. Further choice of colors is possible through application of organic dyes. Some of these are readily absorbed by the chromate finishes to give reds, blues, greens, golds and blacks, along with simulated brass tones which are sufficiently color-fast for indoor service. The primary purpose for use of dyes is color coding of similar parts.

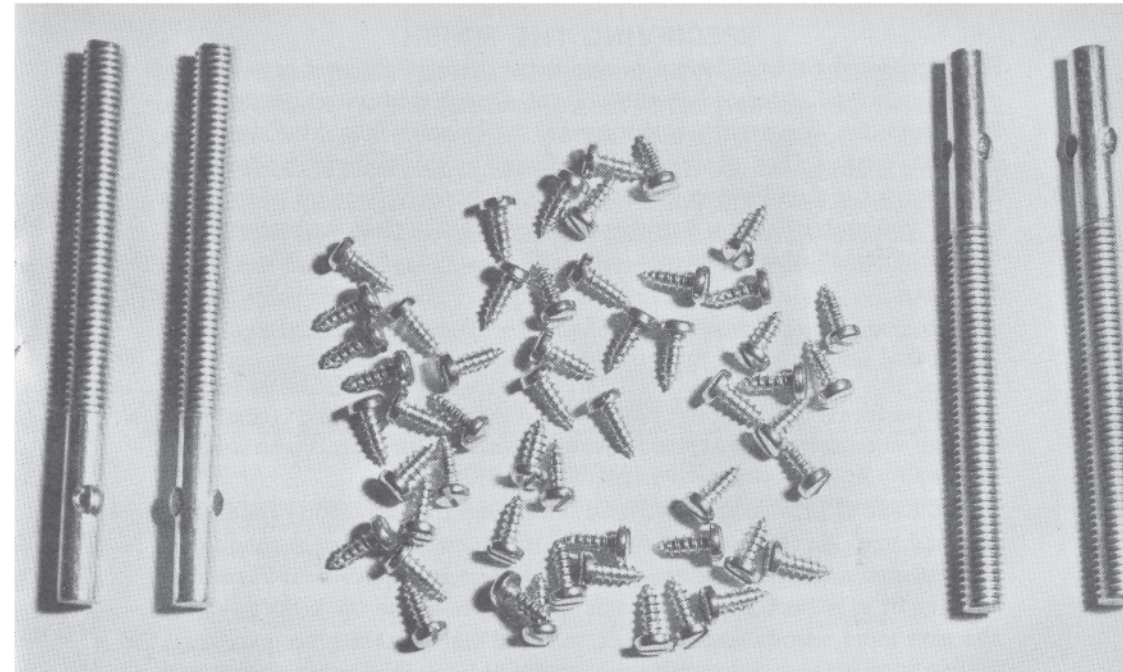


Illustration F – Zinc plated screws and bolts with clear chromate coating.

The chromate finishes are also used to reduce tarnishing and finger-marking and thus improve the shelf life of hardware and appliance parts.

- (c) **Electrical Properties** – The electrical resistance of the chromate finishes varies with the film thickness – i.e., the thinner the film the lower the resistance. In many applications their protective value can be utilized without losing the advantages of low contact resistance and good surface conductivity of cadmium plated steel. A silver bearing black chromate finish is being used both for cosmetic appearance and to improve static grounding of computer housings. Many electronic, electrical and aircraft components are thus treated.
- (d) **Solderability** – Soldering with rosin fluxes is possible on cadmium-plated surfaces treated with clear chromate finishes. However, clear bright coatings on zinc deposits and colored finishes on both zinc and cadmium usually but not always must be removed in the area of a soldering joint. Applications of clear chromate finishes on plated parts for soldering are typified by electronic equipment, business machines, and telephone equipment.
- (e) **Abrasion Resistance** – Most chromate conversion coatings dehydrate to form a relatively hard film which can withstand a moderate amount of wear and handling. The coating does retain entrapped water which, to some extent, enables the coating to “self-heal” or flow back into a scratched area.

## SPECIFYING THE FINISH

Having selected either cadmium or zinc as the coating for a steel or iron component, and having decided whether or not a supplementary chromate finish is required, the designer must now specify the requirements of the system to assure its quality. High quality can be achieved by specifying the appropriate thickness for the application, adhesion, appearance and freedom of the basis metal from embrittlement, together with appropriate tests for assuring that these requirements have been met.

### Thickness

Atmospheric exposure tests in several countries have supported the generalization that the protective value of zinc or cadmium deposits is proportional to their thickness. That is, a steel part coated with one micrometer of zinc will be protected from rusting about twice as long as another part coated with one-half micrometer and exposed at the same time. Thickness is therefore the most important item in a quality specification.

Tables I and II provide recommended thicknesses for high quality finishes on iron and steel. An attempt is made to define four classes of service conditions, namely, mild, moderate, severe and very severe. In case of doubt as to the severity of a planned application one should specify the thickness given for the next more severe class. It should be noted that the tables recognize some applications for very severe service, however, at these thicknesses, mechanical galvanizing (plating) can be used as an alternative to hot dipped coating, metal spraying or other finishes since electroplating becomes economically unfeasible.

Illustration G — Zinc plated tools and hardware with clear chromate coating.



Reliance is not placed upon the various chromate finishes to add significantly to the protective value of the metal coating. Instead, the chromate treatments are employed to improve appearance of the coatings, retard staining and delay formation of voluminous white corrosion products which might interfere with functioning of a component. The thinner chromate finishes are specified when solderability and good electrical characteristics of cadmium-coated electronic equipment must be maintained. Those treatments are also specified for service in which maintenance of appearance and long shelf life are the sole considerations as with thousands of varieties of hardware parts and wire goods.

TABLE I — SUGGESTED STANDARDS FOR QUALITY ZINC COATINGS ON IRON AND STEEL PRODUCTS

Degree of Exposure	Min. Thick (micrometre) (1)	Chromate Finish	Typical Applications
<b>MILD</b> -Exposure to indoor atmospheres with rare condensation & subjected to minimum wear or abrasion	5	none clear iridescent yellow olive drab	screws, nuts and bolts, buttons, wire goods, fasteners
<b>MODERATE</b> -Exposure mostly to dry indoor atmospheres but subjected to occasional condensation, wear or abrasion	8	none clear iridescent yellow olive drab	tools, zipper pulls, shelves, machine parts
<b>SEVERE</b> -Exposure to condensation perspiration, infrequent wetting by rain, cleaners	13	none clear iridescent yellow olive drab	tubular furniture, insect screens, window fittings, builders' hardware, military hardware, washing machine parts, bicycle parts
<b>VERY SEVERE (2)</b> Exposure to bold atmospheric conditions, and subject to frequent exposure to moisture, cleaners and saline solutions plus likely damage by denting, scratching or abrasive wear	25	none	plumbing fixtures, pole line hardware

25.4 Micrometres = 1.0 Mil.

(1) Thickness of the coating after chromate treatment.

(2) Although there exist some applications for heavy electrodeposited coatings for very severe service they are most usually satisfied by hot dipped or sprayed coatings.

**TABLE II – SUGGESTED STANDARDS FOR QUALITY  
CADMIUM COATINGS ON IRON AND  
STEEL PRODUCTS**

Degree of Exposure	Min. Thick (micrometre) (1)	Chromate Finish	Typical Applications
<b>MILD</b> -Exposure to indoor atmospheres with rare condensation & subject to minimum wear or abrasion	5	none clear iridescent yellow olive drab	springs, lock washers, fasteners, tools electronic and electrical parts
<b>MODERATE</b> -Exposure mostly to dry indoor atmospheres but subjected to occasional condensation, wear or abrasion	8	none clear iridescent yellow olive drab	TV and radio chassis, threaded parts, screws, bolts, radio parts, instruments
<b>SEVERE</b> -Exposure to condensation perspiration, infrequent wetting by rain, cleaners	13	none clear iridescent yellow olive drab	washing machine parts, military hard- ware, electronic parts for <b>tropical</b> service
<b>VERY SEVERE (2)</b> Exposure to bold atmospheric conditions and subject to frequent exposure to moisture, cleaners and saline solutions plus likely damage by denting, scratching or abrasive wear	25	none clear iridescent yellow olive drab	

(1) Thickness of the coating after chromate treatment. 25.4 Micrometres = 1.0 Mil.

#### Comparison with Other Thickness Standards

The thickness standards suggested by MFSA in Tables I and II include grades suitable for all uses. In Tables III and IV are listed some of the specifications for zinc and cadmium coatings published by other organizations. MFSA recommendations reflect general agreement with those standards published by other organizations to the extent given in Tables III, IV, V, VI and VII.

#### Protective Value

As indicated earlier, specifying a minimum thickness of a zinc or cadmium deposit is the best way to guarantee protective value of high quality. Some buyers do additionally specify performance in the standard salt spray test as

an acceptance requirement. The salt spray gives cadmium coatings a much better rating than zinc coatings of equal thickness. In actual exposure tests cadmium deposits on steel usually show a superiority over zinc in marine atmospheres, while they are definitely inferior to zinc in industrial atmospheres. The best course to follow is not to rely too heavily on salt spray performance as a measure of rust retarding ability or protective value of zinc and cadmium coatings.

Under normal exposure conditions, a clear or blue bright passivating dip is sufficient to prevent the formation of white corrosion products on zinc or cadmium coatings until the coating has eroded away and red rust starts to appear. There is some evidence<sup>1</sup> that the strong passivation of yellow or olive-drab chromates reduce the galvanic cell protection of the plating and red rusting may be more extensive than without these heavy chromates. This is due to the fact that a larger amount of zinc is dissolved during chromating with these heavier types, leading to a corresponding reduction in zinc thickness and overall galvanic protection.

In the case of salt corrosion, such as marine or road salt conditions, the use of heavier chromate coatings will delay the formation of white corrosion products. Salt spray hours may be useful in measuring the chromate protection in these cases.

The following table is given in ASTM Specification B-201-68, and lists the expected minimum salt spray hours to white corrosion.

**TABLE III – EXPECTED PROTECTION – ZINC**

Type of Coating	Expected Minimum Hours to White Corrosion of Zinc
One-dip colorless (clear bright)	12
Two-dip colorless (clear bright)	24
Black dip	48
Anodic-colorless	48
Anodic-black	96
Iridescent yellow or bronze	96
Anodic-yellow	150
Olive-drab	150

<sup>1</sup>Symposium on Properties, Tests, and Performance of Electrodeposited Metallic Coatings. ASTM Special Technical Publication #197, page 93

**TABLE IV – PUBLISHED SPECIFICATIONS FOR ZINC COATINGS ON STEEL**

Sponsor	Specification	Class or Type	Min. Thick (micrometre) (mil)	
ASTM	B633	Very severe	25	1.0
		Severe	13	.5
		Moderate	8	.3
		Mild	5	.2
Federal	QQ-Z-325a	1	25.4	1.0
		2	12.7	0.5
		3	5.08	0.2
	FF-B-561a FF-H-106a FF-H-111a FF-H-116c WW-T-806b WW-P-541b	lag bolts	5.08	0.2
		locks, door trim	12.7	0.5
		shelf and misc. hardware	12.7	0.5
		hinges	12.7	0.5
		elect. metal tubing	20.3	0.8
		plumbing fixtures	27.4	1.0
Military	MIL-F-14072	ground signal equipment – I	0.5	0.5
		ground signal equipment – II	0.3	0.3

**TABLE V – PUBLISHED SPECIFICATIONS FOR MECHANICAL ZINC COATINGS**

Sponsor	Specification	Class or Type	Min. Thickness (micrometer) (mil)	
ASTM	B695	50	50	2.0
		40	40	1.6
		25	25	1.0
		12	12	0.5
		8	8	0.3
		5	5	0.2
Federal	FF-N-105B		12	0.5
Military	Mil-C-81562	1	76	3.0
		2	51	2.0
		3	43	1.7
		4	25	1.0
		5	13	0.5
		6	8	0.3
American Association of State Highway & Transportation Officials (AASHTO)	M 298	50	50	2.0
		40	40	1.6
		25	25	1.0
		13	13	0.5
		8	8	0.3
		5	5	0.2

**TABLE VI – PUBLISHED SPECIFICATIONS FOR CADMIUM COATINGS ON STEEL**

Sponsor	Specification	Class or Type	Min. Thick (micrometre) (mil)	
ASTM-AES	A165	N.S.	12.7	0.5
		O.S.	7.62	0.3
		T.S.	3.81	0.15
Federal	QQ-B-416b	1	12.7	0.5
		2	7.62	0.3
		3	5.08	0.2
	FF-B-561a FF-H-106a FF-H-111a FF-H-116c	lag bolts	5.08	0.2
		locks and door trim	3.81	0.15
		shelf and misc. hardware	3.81	0.15
		hinges	3.81	0.15
Military	MIL-F-14072	I	12.7	0.5
		II	7.62	0.3

**TABLE VII – PUBLISHED SPECIFICATIONS FOR MECHANICAL CADMIUM COATINGS**

Sponsor	Specification	Class or Type	Min. Thickness (micrometer) (mil)	
ASTM	B 696	12	12	0.5
		8	8	0.3
		5	5	0.2
Military	Mil-C-81562	1	12	0.5
		2	8	0.3
		3	5	0.2

**TABLE VIII – PUBLISHED SPECIFICATIONS FOR MECHANICAL COATINGS OF CADMIUM TIN**

Sponsor	Specification	Class or Type	Min. Thickness (micrometer) (mil)	
Military	Mil-C-81562	1	12	0.5
		2	8	0.3
		3	5	0.2
ASTM	B 635	12	12	0.5
		8	8	0.3
		5	5	0.2

### Adhesion

The coating must remain adherent to the basis metal when subjected to bending, cutting or grinding. There is no accepted standard of adhesion and these tests can only be considered qualitative. In high quality plating the adhesion of metallic coatings is so good that in any destructive test the bond between coating and basis metal does not fail at the interface.

### Appearance

Appearance cannot be readily specified because it involves factors which are not easily assessed, such as brightness, roughness, uniformity of color and freedom from blisters, pits and other surface defects. It is suggested that samples be prepared which are acceptable to both manufacturer and purchaser as standards of quality in appearance.

For chromated finishes the general appearance is automatically specified when the type of finish is selected. However, if the requirement of color is critical, use of standard samples for comparison is recommended.

### Hydrogen Embrittlement

All high strength steel parts with hardness greater than Rockwell C 35 are susceptible to embrittlement caused by absorption of hydrogen during the processing of the steel or in pickling, cleaning or electroplating operations. Cathodic cleaning should be avoided if possible in favor of anodic cleaning and activating. To avoid possible failure of such components on the shelf or in service, due to delayed cracking, it should be specified that they shall be heated after plating for 3 or 4 hours at 191° to 205°C (375° to 400°F) or as prescribed in ASTM Designation B 242.

If immunity from hydrogen embrittlement is a paramount requirement, coating high strength steel parts by mechanical plating should be considered because no hydrogen is introduced into the steel during the plating process itself. It should be noted that the use of this process for the purpose of controlling hydrogen embrittlement to a minimum must recognize the possible embrittling effects of any cleaning and pretreatment procedures. Proprietary zinc and/or cadmium plating processes which deposit zinc or cadmium with little, if any, hydrogen embrittlement should be considered.

## ZINC ALLOY PLATING

Zinc coating of steel components has been thus far considered the most economical and viable industrial finishing process for steel, where sacrificial type corrosion resistance is required. For most applications, zinc finishes

afford from 24 hours to “white” rust and up to 240 hours to “red rust” in accelerated neutral salt spray testing, depending on zinc thickness, type of chromate and availability of organic top coat.

Recently, specifications for much improved corrosion resistance, especially in the automotive industry, prompted the industry to develop new finishing processes. Alloy plating offers many practical possibilities in this respect.

Electrochemically, alloys have different corrosion potentials from their alloying elements, and can be designed to achieve specific properties. Alloys of zinc, if sufficiently high in zinc content, can still maintain an anodic potential to steel, yet remain less active than pure zinc.

In a corrosive atmosphere, this means that the zinc alloy will still protect the steel sacrificially, but will corrode at a much lower rate than zinc. There are several zinc alloys commercially available.

Zinc-iron Zinc-cobalt – Zinc-nickel and Tin-zinc. Except for the latter, zinc accounts for 85-99% of the alloy composition. As in zinc plating, chromate conversion coating as a post treatment is important in improving the overall corrosion resistance of zinc alloys.

### Zinc-Iron

The process produces zinc alloys containing 15-25% iron. The alloy has good weldability, workability and can be adapted to commercially electroplated strip steel. The alloy composition and process can be varied to enhance weldability or adhesion of electropainting processes. Black chromating is the most suitable for this type of alloy Table IX – A typical bath composition.

TABLE IX

### Zinc-Iron

Typical chemical bath compositions. Acid type, used in strip line plating.

Ferric Sulphate	200-300 g/L
Zinc Sulphate	200-300 g/L
Sodium Sulfate	30 g/L
Sodium Acetate	20 g/L
Organic Additive	5 g/L

### Zinc-Cobalt

Commercially available processes are similar to low ammonia or ammonia free acid chloride zinc baths. Some newer baths operate on the alkaline side. The deposit contains from 1-3% cobalt. The acid type bath has a higher cathode efficiency, and reduced hydrogen embrittlement, but its plating thickness distribution varies substantially between low and high current density areas. Table X – Typical bath composition. Chromate conversion coatings in iridescent, black and yellow are available.

**TABLE X**

**Zinc-Cobalt**

**Typical Acid Type Baths**

Zinc Chloride	80-90 g/L	80-90
Pot. Chloride	150-200 g/L	50-150 g/L
Ammon. Chloride	—	50-70
Boric Acid	20-30 g/L	—
Cobalt Chloride	1-20 g/L	1-20 g/L
Organic Additives		
pH	5.0-6.0	
Temperature	25-40 deg C	
Cathode C.D.	1.0-4.0 A/dm sq	
Anodes	Zinc	

**Alkaline Type Baths**

Zinc Oxide	10-20 g/L
NaOH	80-150 g/L
Cobalt (additive)	1.0-2.0 g/L
Organic Additives	As specified
Temperature	25-40 deg C
Cathode C.D.	0.1-4 A/dm sq
Anodes	Zinc

**Zinc-Nickel**

There are two types of zinc-nickel processes currently available commercially. Acid and alkaline non cyanide types. Alloys deposited contain from 5 to 15% nickel. Corrosion resistance improves with nickel content up to 15-18% but the deposit becomes more noble and loses its sacrificial protection property. Chromate film formation was found to be at optimum in the 5-10% nickel content range. Above this range the deposit tends to be passive and chromating becomes very difficult.

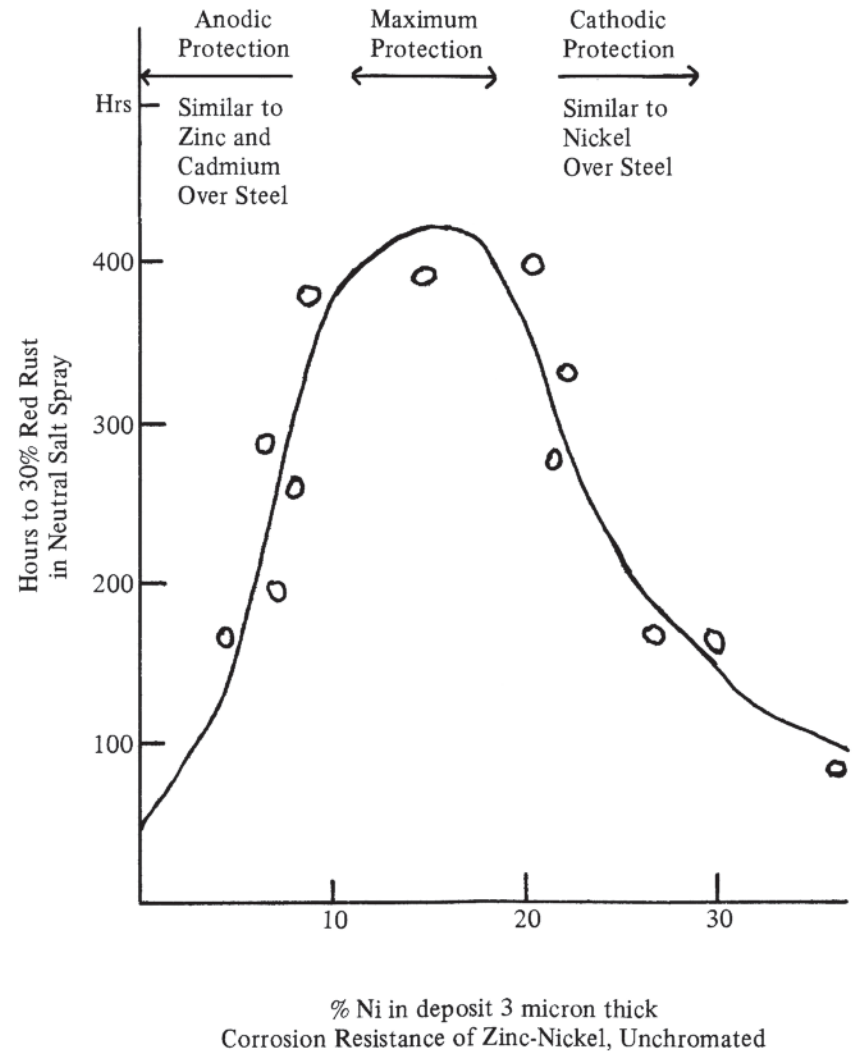
Of all the available zinc alloys, zinc-nickel has consistently produced the highest corrosion protection as shown by accelerated corrosion testing, with the exception of the SO<sub>2</sub> (Kesternich) test which shows zinc-cobalt to be better and equal to zinc.

One advantage of zinc-nickel alloy processes is their capability of retaining a higher corrosion resistance after forming and after heat treating the plated chromated parts. This is of important significance in industries that require these manufacturing steps after plating. Brake and fuel lines and other under the hood components are typical of such applications.

Another important area of application for zinc-nickel alloys, particularly the alkaline type, is their potential as a substitute for cadmium plating. In view of the recent stringent restrictions imposed by regulatory agencies on

cadmium, the search for adequate replacement has been going on for the past several years. The retention of high corrosion resistance after baking and overall performance compared to cadmium plating makes this alloy a favorable candidate for this substitution.

**TABLE XI**



**TABLE XII**

**Typical Bath Composition**

**Zinc-Nickel**

**Acid Type**

Zinc Chloride	130 g/L	120
Nickel Chloride	130 g/L	110
Potassium Chloride	230 g/L	—
Ammonium Chloride	—	150
Organic Additives		
pH	5-6	5-6
Cathodic C.D.	0.1-4.0 A/dm sq	0.5-3 A/dm sq
Current Distribution, zinc	80%	60%
Current Distribution, nickel	20%	40%
Temperature	24-30 deg C	35-40 deg C
Anodes	Zinc and Nickel — connected to two separate rectifiers	

**TABLE XIII**

**Typical Bath Parameters Comparison  
(Rack & Barrel)**

**Conventional Alkaline Non Cyanide**

**Alkaline Zinc-Nickel**

**Chemical Composition**

NaOH	100-120 g/l	100-128 g/l
Zinc	10-12 g/l	6-12 g/l
Nickel		0.7-1.5 g/l
Zinc:Nickel	—	6-7.1
Organic Additives	—	

**Operating Controls**

Temperature	21-35 deg C	20-32 deg C
Anodes Zinc & Steel	Zinc & Steel	Zinc & Steel
Voltage 10-12 V	10-12 V	10-12 V
Anode C.D. 1.5-3.0 (amp/dm sq)	1.5-3.0	4.0-6.5
Cathode C.D. (amp/dm sq)	1.0-4.5	1.0-4.5
Filtration Mechanical	Continuous	Continuous
Agitation (Rack)	Recommended	Recommended

**Chromating of Zinc Alloy Finishes**

Since the zinc alloys assume new chemical activity properties, conventional chromates are not suitable for their passivation. Special chromating solutions are designed for these coatings and due to the alloying elements, produce characteristically strong iridescent films. Heavier films such as bronze, green-purple iridescent and black give the highest corrosion resistance, and are usually specified for optimum performance.

**ZINC ALLOYS AVAILABLE TO REDUCE ACTIVITY WITHOUT REDUCING SACRIFICIAL PROTECTION**

**Salt Spray Test Results:**

Corrosion resistance to red rust @ 8mm (.003 in.) thickness

Zinc 250 hours	Zinc-Nickel — 1,000 hours
Zinc-Iron — 350 hours	Tin-Zinc — 1,000 Hours
Zinc-Cobalt — 500 hours	

**Tin-Zinc**

This is an alloy of 70-90% tin, 30-10% zinc electrodeposited from either a cyanide type bath or from a newly commercially available neutral non cyanide system as well as acid types.

Tin-zinc is more expensive than other zinc alloy baths, but offers high corrosion resistance to salt water as well as sulfur dioxide, as well as excellent solderability and deposit ductility.

Generally, tin-zinc deposits are satin to semi-bright as plated. A top layer of bright zinc plate can be used where bright deposits are required. Special cast tin-zinc anodes are used for the process.

Chromate passivation on tin-zinc alloys is generally limited to yellow or clear applied electrolytically. A top coat of conventional zinc allows the use of any of the available conventional chromates.

**TESTING THE FINISH**

**Thickness**

There is no practical method for measuring the thickness of chromate conversion coatings, although electrical impedance measurements are useful in characterizing the coatings. The appearance of such finishes itself is an index of relative thickness because the olive drab films are known to be thicker than the clear finishes, while the iridescent yellow films are of an intermediate thickness. For the metal coatings there are several methods of test for thickness, some being destructive of the part tested, others not:

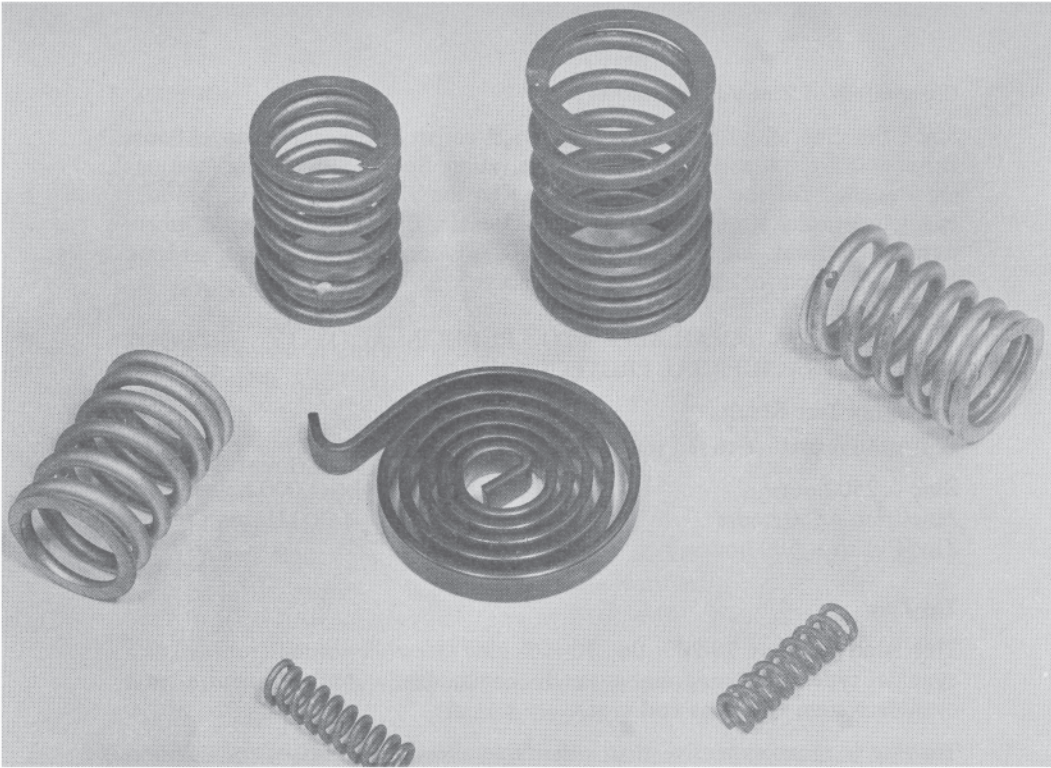


Illustration H — Cadmium plated springs with black and olive chromate coatings.

- (a) **Microscopical Method** — The part under test is cut on a plane perpendicular to a significant surface and is mounted for metallographic examination. The cross-section is polished and etched to contrast the plated coating with the basis metal. The thickness is then measured optically in a microscope at a magnification great enough to permit measurements of thickness with an accuracy of plus or minus one micrometre (0.00004 inch) or one percent of the coating thickness, whichever is greater. The method is obviously destructive. Because of the skill required by the operator and the time involved, it is not ordinarily used for production testing. Where there is disagreement in thickness measured by other methods the microscopic is generally accepted as the referee test. This method has been described as given in ASTM Designation B 487.
- (b) **Coulometric Methods** — Instruments are available which determine the thickness of zinc and cadmium coatings on steel automatically by recording the number of ampere-minutes or coulombs required for a controlled anodic current to dissolve the coating from a small, well defined area on the surface. Although

the test destroys the coating it is rapid and simple. This method is described in ASTM Designation B-504.

- (c) **Magnetic Methods** — Since zinc and cadmium are non magnetic while iron and steel are magnetic, it is possible to determine the thickness of these coatings by commercially available instruments which employ the magnetic field principle.

Instruments are available that measure the force necessary to detach a small magnet from the surface of the finished part. Other instruments utilize the reluctance of a magnetic flux passing through the coating and basis metal to measure the thickness. Both types of instruments are calibrated against standards of known thickness. The tests are non-destructive and rapid.

Results are well within 10% of the true thickness. ASTM Designation B-499 covers the magnetic methods.

- (d) **Destructive Methods** — Dropping and jet tests destroy the coating but not the part. They determine thickness by measuring the time required for penetration through the coating to the basis metal by the action of a steady stream of drops or a jet of a corrosive solution. Reproducibility of  $\pm 5\%$  may be achieved. The solution is chosen so as to provide a constant rate of attack of the coating. ASTM Designation B 555 specifies use of a chromic acid — sulfuric acid solution for drop testing zinc and cadmium coatings on steel.
- (e) **Weight Loss on Stripping** — A test popularly used to determine average thickness of zinc or cadmium deposits over the entire surface of a part depends upon measuring the loss in weight of the part after subjecting the coating to chemical stripping. From the area of the surface and density of the deposit, thickness can be calculated. The method is destructive, not rapid and does not determine local thickness. It does find use in determining the thickness of small, barrel plated parts.

#### Protective Value

- (a) **Salt Spray Test** — The salt spray test has been used to assess the protective value of zinc and cadmium coatings however the results do not correlate with any given service exposure. At best the test is only able to distinguish very poor from very good coatings by picking out bare areas or other areas where the coating is very thin. Although ASTM does not recommend the salt spray test for determining the protective value of zinc and cadmium coatings, the procedure is described in ASTM Designation B 117. Most purchasers do use the salt spray test to assess the quality of chromate treatments on zinc and cadmium by specifying the number of hours to appearance of white corrosion products on a significant

surface. ASTM Designation B 201, Tentative Recommended Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces, is applicable and suggested performance is indicated in Tables I and II.

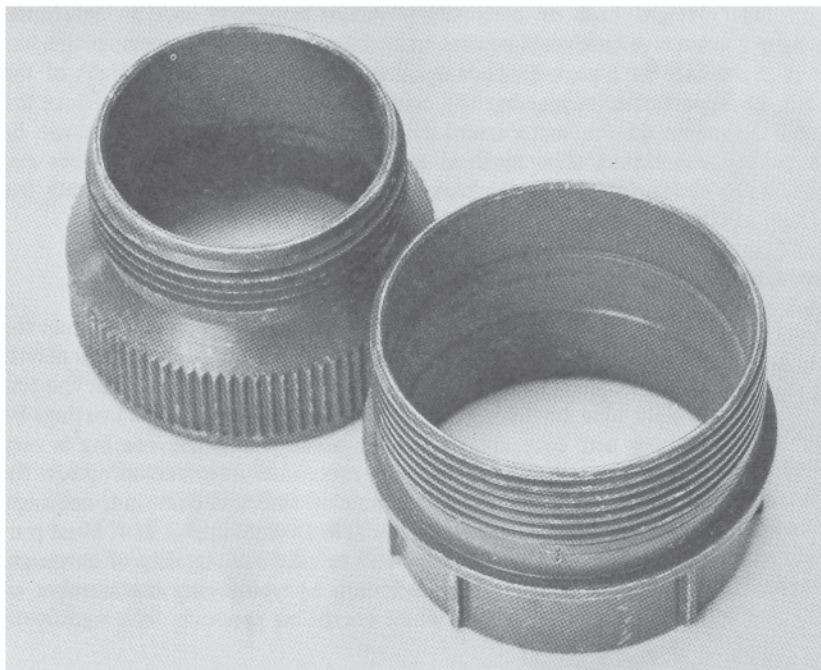
- (b) **Lead Acetate Spot Test** — The presence of clear chromate finishes is often hard to detect visually. On zinc or cadmium coatings such films can be detected by spot testing with a drop of solution containing 5 percent lead acetate in water. The time elapsed to the appearance of a colored spot is compared with the time required for a spot to appear on an unchromated coating. There is no valid correlation with the salt spray test.

### Adhesion

While there is no accepted standard test for adhesion of zinc and cadmium coatings, qualitative methods are sometimes agreed upon which involve bending, twisting, filing or otherwise maltreating the deposit. It is agreed that no separation of the coating should occur in such tests.

For chromate finishes a qualitative test is sometimes used which indicates degree of adhesion and at the same time tells something about its abrasion resistance. The chromated surface is rubbed with a gritless soft gum eraser for 2 or 3 seconds by hand (about 10 strokes) using moderate pressure and a two-inch stroke. The chromate film should not be worn through to the zinc or cadmium layer as a result of this treatment.

Illustration 1 — Cadmium plated aircraft connector with olive drab chromate coating.



## GLOSSARY OF METAL FINISHING TERMS\*

**Adhesion** — The attractive force that exists between an electrodeposit and its substrate that can be measured as the force required to separate an electrodeposit and its substrate.

**Anode** — The electrode in electrolysis at which negative ions are discharged, positive ions are formed, or other oxidizing reactions occur.

**Anodic Chromate Coating** — A chromate conversion coating produced by making the work the anode of an electrolytic cell containing a chromate solution.

**Barrel Plating** — Electroplating of small parts in bulk in a rotating container.

**Basis Metal** — Metal upon which coatings are deposited.

**Bright Dip** — A solution used to produce a bright surface on a metal.

**Bright Plating** — A process that produces an electrodeposit having a high degree of specular reflectance in the as-plated condition.

**Cathode** — The electrode in electrolysis at which positive ions are discharged, negative ions are formed, or other reducing reactions occur.

**Chromate Conversion Coatings** — A coating produced by chemical or electrochemical treatment of a metallic surface that gives a superficial layer containing compounds of the metal and the chromium constituents of the processing solution.

**Coloring** — (1) The production of desired colors on metal surfaces by chemical or electrochemical action. (2) Light buffing of polished metal surfaces for the purpose of producing a high luster.

**Conversion Coating** — A coating produced by chemical or electrochemical treatment of a metallic surface that gives a superficial layer containing a compound of the metal.

**Corrosion** — (1) Gradual solution or oxidation of a metal. (2) Solution of anode metal by the electrochemical action in the plating cell.

**Covering Power** — The ability of a plating solution under a specified set of plating conditions to deposit metal on the surfaces of recesses or deep holes. (Distinguished from throwing power).

**Drag-Out** — The solution that adheres to articles removed from a processing tank.

**Electrolysis** — Production of chemical changes by the passage of current through an electrolyte.

**Electrolyte** — (1) A conducting medium in which the flow of current is accompanied by movement of matter. Most often an aqueous solution of acids, bases, or salts, but includes many other media, such as fused salts, ionized gases, some solids, etc. (2) A substance that is capable of forming a conducting liquid medium when dissolved or melted.

**Electroplating** — The electrodeposition of an adherent metallic coating upon an electrode for the purpose of securing a surface with properties or dimensions different from those of the basis metal.

**Hydrogen Embrittlement** — Embrittlement of a metal or alloy caused by absorption of hydrogen during pickling, cleaning or plating.

**Mechanical Galvanizing** — A process similar to mechanical plating except

that plate thicknesses to 3 mils may be obtained.

**Mechanical Plating** The formation of an inherent metallic coating upon a basis metal by impingement of the coating metal against the basis metal substrate by solid particles, usually glass impact media.

**Metal Distribution Ratio** — The ratio of the thicknesses of deposit upon two specified areas of a cathode. See throwing power.

**Microinch** — One millionth of an inch, 0.000001 in.=0.001 mil.

**Micrometre (Micron)** — One millionth of a meter.

**Mil** — One thousandth of an inch, 0.001 in. = 25.4 micrometres.

**Peeling** — The detachment or partial detachment of an electrodeposited coating from a basis metal or undercoat.

**Pit** — A small depression or cavity produced in a metal surface during electrodeposition or by corrosion.

**Sacrificial Protection** — The form of corrosion protection wherein one metal corrodes in preference to another, thereby protecting the latter from corrosion.

**Tarnish** — (1) Dulling, staining or discoloration of metals due to superficial corrosion. (2) The film so formed.

**Throwing Power** — The improvement of the coating (usually metal) distribution over the primary current distribution on an electrode (usually cathode) in a given solution, under specified conditions. The term may also be used for anodic processes for which the definition is analogous.

**Work (Plating)** — The material being plated or otherwise finished.

\*Above definitions have been taken from ASTM B 374, Definitions of Terms Relating to Electroplating and have been abbreviated where appropriate for this text.

## SOURCES OF INFORMATION

### Societies and Associations

**American Electroplaters and Surface Finishers Society**  
12644 Research Parkway  
Orlando, Florida 32826  
(407) 281-6441

**American Society for Testing and Materials (ASTM)**  
1916 Race Street  
Philadelphia, Pennsylvania 19103  
(215) 299-5400

**Metal Finishing Suppliers' Association, Inc. (MFSA)**  
801 N. Cass Avenue  
Westmont, Illinois 60559  
(708) 887-0797

**National Association of Metal Finishers (NAMF)**  
111 E. Wacker Drive  
Chicago, Illinois 60601  
(312) 644-6610

**Cadmium Council, Inc.**  
292 Madison Avenue  
New York, New York 10017  
(212) 578-4750

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